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Keywords

Mainstreaming of research, Research-teaching linkages, Supercomplexity, Transitional learning, Short-term research, Undergraduate medical students

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Abstract

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Introduction

Much debate regarding the existence of a research-teaching nexus has centred on the potential of staff participation in research to enhance the quality of their teaching to the betterment of student learning. (Hounsell, 2002) On the one hand, pressure on staff time fuelled by research assessment exercises may be viewed as a limiting factor in terms of accessibility of senior staff for teaching support. (Gibbs, 2002) On the other hand, being able to impart knowledge of cutting edge research to the learner may lead to more effective engagement. (Zamorski, 2002) The latter view in particular, like many of its genre, challenges the traditional model of the relationship between research and teaching, where the two are viewed as poles apart. (Brew, 2006) Nevertheless, it is intertwined with the conventional perspective of academic staff being the likely participants in research activities and student learning being accomplished through knowledge transmission from the expert.

Largely due to the work of Margaret McVicar, who in 1969 was founder of the Undergraduate Research Opportunities Program (Pender, 2009), undergraduate research has become a very highly established practise in the USA, with many other countries, including the UK, lagging considerably behind. The value, however, of students participating in research is reflected in the following comments by Healey in support of students as research participants:

“... learning by doing is an effective way for students to benefit from staff research. This is because active learning is more likely to encourage students to adopt a deep approach to learning than is the transmission model, which may encourage a surface approach. Further evidence comes from the work of Baxter Magolda (1999), who shows that students involved in research-based inquiries develop more sophisticated levels of intellectual development.” (Healey, 2005b)

These comments highlight the vital benefits to *learning* which arise from student participation in research without the requirement that all participants should validate these benefits in terms of their resolve to pursue research careers either prior to or after such learning. Rather, here, research is viewed primarily as a pedagogical tool rather than an end in itself. In keeping with earlier work, (MacDougall & Riley, 2010) the particular model of research assumed in the current study is one in which:

- students have the freedom to contribute new knowledge to an existing community of research practise and sense the authenticity of their roles as researchers

and

- there is flexibility across student projects in the weight assigned to criteria within assessment rubrics so as to reflect the wide variation in content across these projects. (Riley, 2009)

The possibility of medical students acquiring freedom in the above sense has already been acknowledged within the context of assessing supervisor practices for initiating fledgling researchers into “research communities of practice”. Here, it was noted that the majority of recommendations provided by respondent supervisors had “the potential to take the new learner beyond the stage of initiation to that of integration within their community of practice”. In turn, it was suggested this finding may be indicative of a more general tendency in medical education in particular of encouraging learners to operate beyond the periphery. (MacDougall & Riley, 2010) Moreover, the latter types of project have been introduced to undergraduate medical curricula to facilitate student choice in terms of topics explored, including areas “not always given a true representation in medical curricula” (Riley, Ferrell, Gibbs, Murphy, & Smith, 2008). Thus, it ought to be a realistic ideal to expect of such early researchers that they should encounter novel findings, both relative to their own and their supervisor’s specialist knowledge. Indeed, this is to be expected given that SSCs are recognized more generally, as having the potential to serve as “a fertile breeding ground for new ideas” (Riley et al., 2008).

In evaluating the success of student research under the above model as a paradigm for effective learning within the context of undergraduate Medicine, it is particularly important to bear in mind, however, that the content of learning is most meaningful to the learner where the link to future professional practise is explicit. More generally, it makes sense to consider what type of world we are preparing our students for. Barnett provides his own perspective on this issue through his notion of *supercomplexity*, which he presents in the following way:

“...professional life is increasingly becoming a matter not just of handling overwhelming data and theories within a given frame of reference (a situation of complexity) but also a matter of handling multiple frames of understanding, of action and of self-identity. The fundamental frameworks by which we might understand the world are multiplying and are often in conflict. Of the multiplication of frameworks, there shall be no end.

“It is this multiplication of frameworks that I term supercomplexity. It increasingly characterizes the world in which we all live. Working out its operational, cognitive and pedagogical implications for the university constitute much of the challenge ahead.” (Barnett, 2000)

In Medicine, Barnett's notion of supercomplexity is consistent with the idea that physicians can no longer be regarded as the "professionals of the establishment" contesting with their "radical critics" in the sense acknowledged by Schön in the 1980s. (Schön, 1999) Where the physician is confined to a tacit framework in defending their cause, they are likely to encounter complexity through the sheer burden of subject-specific knowledge within their discipline. However, in an era of public accountability, there is a greater need for physicians to survive in terms of retaining their professional credibility. Correspondingly, they are obliged to move closer to Schön's ideal of reflecting-in-action "on their previously tacit frames" under an awareness of the "variety of frames available to them" arising from other disciplines. Such multiple frames (or frameworks), including those introduced by the patient, substantiate Barnett's idea of supercomplexity within the context of Medicine. This idea has been illustrated in the medical literature through the following observations:

"As medicine becomes more complex and information technologies transform decision making, physicians must learn not only how to apply new tools and technologies more effectively but also new ways of decision making that foster multiple inputs [including those from librarians and informaticians]..."(Moore, 2011)

Furthermore, external clinical governance contributes an additional framework to supercomplexity. In particular, physicians may sense the need to learn the "craftsmanship" of medicine or, the art of "reflective practice" through attending to the immediate needs of the individual patient (Alaszewski, 2002; Brown & Calnan, 2011). However, there is a working tension between this need and that of processing the bureaucratic guidelines – the protocols – laid down for clinical decision making in a standardized sense. In turn, in some specialisms such as the treatment of paediatric cancer, (Darzi, 2008) the latter continually have the potential to become outdated in response to medical advances. Thus, even where protocols are formulated in response to a watershed in physicians' prior failures to adequately manage risk, (Alaszewski, 2002) uncertainty prevails at a more granular level in addressing individual clinical cases.

In recognizing the centrality of supercomplexity to medical practise, it is important to acknowledge the key responsibility that the university has from a pedagogical perspective in preparing its medical students (among other students) to live with this phenomenon. Key strategies in this respect (Barnett, 2000, 2007) are:

- 1) promotion of interdisciplinarity

and

- 2) fostering student capacity to live with uncertainty through risk-taking behaviour.

Recommendations for implementing strategy 1 within undergraduate medical curricula have already been considered under the overarching theme *Fostering a holistic perspective of the subject area(s)*. (MacDougall & Riley, 2010) The relevance to clinical practise is clear when one considers, not simply the historical shift which has taken place from ad hoc collegiate chats in the corridor to routine multidisciplinary team meetings (Darzi, 2007) but also, the nature of supercomplexity in 21st century Medicine as highlighted above.

Strategy 2 promotes an environment where learning is, not only more personalized, leading to greater intentionality but also, more authentic, which is essential to

transformative learning. Its relevance on an international scale to the training medical students is clear from the medical literature. For example, Moore reports that,

“Almost every statement of medical competencies includes the need for physicians to be able to make independent decisions in the face of uncertainty.” (Moore, 2011)

Similarly, Brown and Callan note that,

“Notions of risk and corresponding uncertainty are at the very core of medical practice – in its application of evolving technology and expertise in seeking to alleviate morbidity and mortality.”(Brown & Calnan, 2011)

The close affinity between making “decisions” and exposure to risk-taking is reflected in the types of errors reported in the literature including “iatrogenic damage, waste and overtreatment” and is reinforced by reported difficulties findings which physicians encounter when attempting to interpret research findings soundly and apply them appropriately in their own clinical practise. (Altman, 2002; Moore, 2011; Windish, Huot, & Green, 2007) While “medicine is inescapably about managing uncertainty” (Brown & Calnan, 2011) and striving for risk minimization, the creation of learning environments for medical students throughout their curricular training which require the management of risk and uncertainty is likely to make such experiences more natural and manageable.

In preparing students for a supercomplex world, Barnett also views it as the responsibility of the academic researcher to progress from norm endorsing to revolutionary forms of research so as to provide alternative frameworks of understanding to the wider world. The need for this is evident in medicine where 21st century patients are more at liberty to negotiate their own treatment regimes. The range of advice on diagnosis and treatment which is now readily available online, much of which may challenge conventional medicine, has contributed considerably to this culture, as has patient access to medical records. From this perspective, undergraduate medical students ought to have been exposed to revolutionary research within their learning experience, either vicariously or better still, directly, in order that they have the necessary mindset to formulate an adequate and up-to-date evidence base in response to patient concerns. It is of interest, therefore, to explore to what extent the latter of these two possibilities has been realized within the context of short-term research projects in undergraduate medicine.

The above observations set the scene for exploring the evidence that the educator’s preparation of a research environment for the student enhances the learning experience for the student (thus benefiting teaching). It is also of interest, however, to explore the benefits to teaching in terms of curriculum design. The research-teaching nexus to be investigated here, therefore, is that defined:

- a) primarily in terms of the direct benefits to teaching through the supervisor designing the student research environment as a pedagogical tool to enhance student learning

and

- b) at a secondary level, in terms of the indirect benefits to teaching through revisions to the existing curriculum resulting from the findings of student research.

As a means of investigating supervisor practises for evidence of enhancing learning through student research as highlighted under a), above, the current study will focus on

opportunities both for *deep learning* and for *preparing students for a supercomplex world*. This work will be informed by the writings of Marcia B Baxter Magolda and Ron Barnett, among others. Thus, a part of this study is closely related to previous work where it was observed that deep learning can take place where the student is free to construct knowledge within their community of research practise, and cross-disciplinary research was seen as a means through which this could be achieved. (MacDougall & Riley, 2010)

While both a) and b) refer to the idea of research benefiting teaching, the potential reciprocity of the two relationships lies in the idea that while a) reflects the input of the staff educator to the learning experience of the student researcher, b) reflects the returns to the staff educator in their own curriculum design based on the activities of the student researcher. As in earlier work, the supervisor is viewed here as an educator responsible for designing the research process to optimize student learning.

Methodology

The model of student research considered in this study is encountered within the Year 4 Student Selected Component (SSC4) programme at the University of Edinburgh, Scotland. This mandatory programme involves clinically related projects which typically take place over a 14-week period, leading to the submission of a project report of about 3,000 words. These projects are also recognized explicitly within the course materials as having the potential to increase student research skills and as counting toward summative assessment, with the project mark being assigned a weight of 14% in deciding end-of-year marks. The current practise is that two (possibly non-consecutive) weeks of the SSC4 period are allocated exclusively to SSC4 work. For the remainder of the time, students are expected to manage time spent on both SSC4 work and other curricular activities, including exam preparation.

Conduct of Survey

The questionnaire used in this study (Additional file) was designed and implemented using the survey design tool SurveyMonkey, Professional version. The target population was all staff who had supervised SSC4 projects at the University of Edinburgh during 1995 – 2008. Contact details were obtained mainly from comprehensive lists already held by the SSC4 secretary and also, through pursuing previous colleagues of the contact and using online search engines, including www.search.com and a staff search engine on the University of Edinburgh's website.

To optimize the response rate, supervisors were emailed 14 days in advance of sending out the survey to brief them on the purpose of the study and to encourage them to consider the project proposal available on the appropriate Higher Education Academy website. The survey underwent test-runs prior to distribution both through multiple checks by the Principal Investigator, who designed the questionnaire, and a confirmatory check by the Director of SSCs at Edinburgh. The survey was kept open over the period 10 October 2008 to 14 April 2009 and provision was made to return to unanswered questions so as to allow for busy schedules and the need to verify information which was not immediately available.

In keeping with the objectives of the study, the majority of questions within this questionnaire were designed so as to reflect the three themes

- facilitating higher forms of learning,
 - equipping students for survival in a supercomplex world
- and

- impact of student research on curriculum design.

In relation to the first of these themes, Baxter Magolda's Epistemological Reflection Model (Baxter Magolda, 1992) was incorporated into the questionnaire (Q. 19) as a basis for weighing up the evidence for a qualitative shift in student ways of thinking about their subject area(s) and the expectations they hold of their supervisor and other colleagues in contributing to their learning development.

In the results section of this paper, individual survey questions corresponding to study findings will be provided in brackets, either within the main text, figure header or table captions, so as to allow the reader to refer to the relevant parts of the questionnaire for more details.

Q. 18 from the questionnaire has already been used in a preliminary study reporting on good supervisory practise in initiating undergraduate medical students into communities of research practice. (MacDougall & Riley, 2010) Most of the remaining questions not referred to in the results section are intended for consideration in a follow-on publication.

Data Preparation and Analysis

Response data provided by SurveyMonkey were downloaded in CSV format, transferred to MS Excel and subsequently re-coded and simplified to allow convenient transfer to PASW (Predictive Analytics SoftWare) Version 17.0 for statistical analysis.

For consistency with earlier work, (MacDougall & Riley, 2010) the procedure of assigning number of students supervised to the stage of project completion to the categories '1', '2 - 5', '6 - 10' and '> 10' was carried forward to the current study and these categories were in turn used to represent levels of supervisory experience.

Assuming a significance level of 0.05, the chi-square test of association with Yates' correction was used to test for evidence for an association between the two most popular reasons which supervisors reported for taking on the supervisory role. This subsidiary test was carried out purely for completeness to assess the availability of evidence for a negative or positive association between supervisors' research and teaching aspirations.

Results

Out of the 324 individuals within the target population for the survey, 217 (67%) responded. These respondents collectively represented a total of 126 specialist areas, within which they recalled having taught SSC4 students under their supervision. While a majority of 96 respondents (44.2%) reported having supervised 2 – 5 students to completion, a further 83 (38.2%) reported having acquired more experience, with 10 of these respondents having supervised more than 20 students.

In terms of reasons for taking on the supervisory role (Q. 3), the response category *Was already involved in research where I could see obvious opportunities for student input* proved to be far the most popular, assuming 144/217 (66.4%) of responses. Interestingly so, 83 (38.2%) of supervisors declared that they *Saw this as an opportunity to get involved in teaching*, with this choice being the second most popular. The third most popular reason, which 55 (25.3%) of supervisors opted for, was *Recognized this as opportunity to enhance my personal professional development*. These three response categories dominated the response data relative to the other responses.

There was a lack of evidence for a significant negative or positive association in terms of supervisors opting simultaneously for the two most popular choices above ($\chi^2 = 0.029$,

$p = 0.864$, $n = 217$). In terms of magnitude of any apparent correlation, this result was supported by a correspondingly low value of -0.022 for the phi coefficient. In addition, supervisors provided a range of alternative reasons in much lower frequencies. Further to post-hoc classification of these reasons, the three most popular suggestions were found to fall under the categories below, which appear in uncondensed form to aid clarity:

*raise profile of the topic or the department, alert student to professional issues within the supervisor's field: **10 (4.6 % of) respondents;***

*approached by student directly or indirectly, such as through recommendation of other clinician who did not feel qualified to supervise student's area(s) of interests: **9 (4.1% of) respondents;***

and

*personal sense of responsibility in own capacity as teacher or researcher or both: **8 (3.7% of) respondents.***

Facilitating higher forms of learning

Table 1 summarizes supervisor views on transitions in learning stages based on Baxter Magolda's epistemological reflection model.

Table 1. Comparison of learning stages for research students prior to and after research based on Baxter Magolda's Epistemological Reflection Model^a

Prior learning stage	Subsequent learning stage					Total
	Unsure	Obtains knowledge from instructor	Understands knowledge	Thinks for self, etc. ^b	Exchanges and compares, etc. ^b	
Unsure	13 6.2%	0 0.0%	1 0.5%	0 0.0%	1 0.5%	15 7.1%
Obtains knowledge from instructor	4 1.9%	4 1.9%	18 8.6%	53 25.2%	13 6.2%	92 43.8%
Understands knowledge	1 0.5%	0 0.0%	4 1.9%	32 15.2%	21 10.0%	58 27.6%
Thinks for self, etc.	1 0.5%	0 0.0%	0 0.0%	5 2.4%	35 16.7%	41 19.5%
Exchanges and compares, etc.	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 1.9%	4 1.9%
Total	19 9.0%	4 1.9%	23 11.0%	90 42.9%	74 35.2%	210

a. Main diagonal elements are highlighted in bold to help in identifying transitions.

b. Titles of learning stages have been abbreviated simply to save space (see Q. 19 for original version).

Within the corresponding free text comments, 16/210 (7.6%) of supervisors indicated implicitly, if not explicitly, the difficulty of generalizing progress across the students they had had prior experience of supervising. In relation to this, a number of respondents

offered instructive contributing factors for explaining such variation, including whether the student had completed an intercalated honours degree (which would inevitably have involved some research and dissertation work), student personality types and the ability to balance SSC4 work with other areas of the curriculum, including exam preparation. In terms of progression in stages of learning, the following contribution by one supervisor reflects a belief in the over-arching influence of student characteristics rather than the role of the supervisor in designing the research project to enhance quality of learning:

“Reflects students' own capacity, maturity and enthusiasm much more than anything”.

Further constructive feedback was also obtained in relation to the application of Baxter Magolda's model to the research experiences of undergraduate medical students. In particular, one supervisor recognized the need for the descriptors to reflect progress in analytical thinking. Another supervisor advised that for any one student, descriptors from the table should vary according to learning task, contrasting a prior rating of 1 in “questionnaire design” with a prior rating of 4 in “other” learning tasks by way of example. A further respondent highlighted the constraints that the types of project they supervised were likely to place on the student's ability to progress through Baxter Magolda's stages of learning. In particular, requiring the student to conform to the “fairly rigid” methodology recommended by SIGN (The Scottish Intercollegiate Guidelines Network) to the National Health Service in Scotland was an obstacle to independent problem solving.

Indicators of levels of student contribution to existing research and autonomy in research design are summarized in Tables 2 - 3.

Table 2. Contribution which SSC4 students tend to make to research life of supervisor's department or team^{a,b}

Contribution	Count (%)
Not applicable - I am not involved in promoting research	22 (10.6%)
SSC4 projects tend to be stand-a-lone research projects designed primarily to fit within the SSC4 timetable rather than being an integral part of an ongoing research program.	97 (46.9%)
Output from SSC4 projects tends to make a constructive contribution to our knowledge of specific subject areas within one or more research programs.	88 (42.5%)
Total	207

a. 'SSC4' denotes 'Year 4 Student Selected Component'.

b. See Q. 22

Table 3. Extent to which individual SSC4 students contribute to the formulation of the underlying questions, hypotheses or objectives which underpin the project by comparison with supervisor^{a,b}

Extent of student contribution	Count (%)
Student does not contribute at all	15 (7.2%)
Much less so	59 (28.5%)
Less so	65 (31.4%)
Roughly equally so	36 (17.4%)
More so	13 (6.3%)
Much more so	4 (1.9%)
Student has full control	2 (1.0%)
Other	13 (6.3%)
Total	207

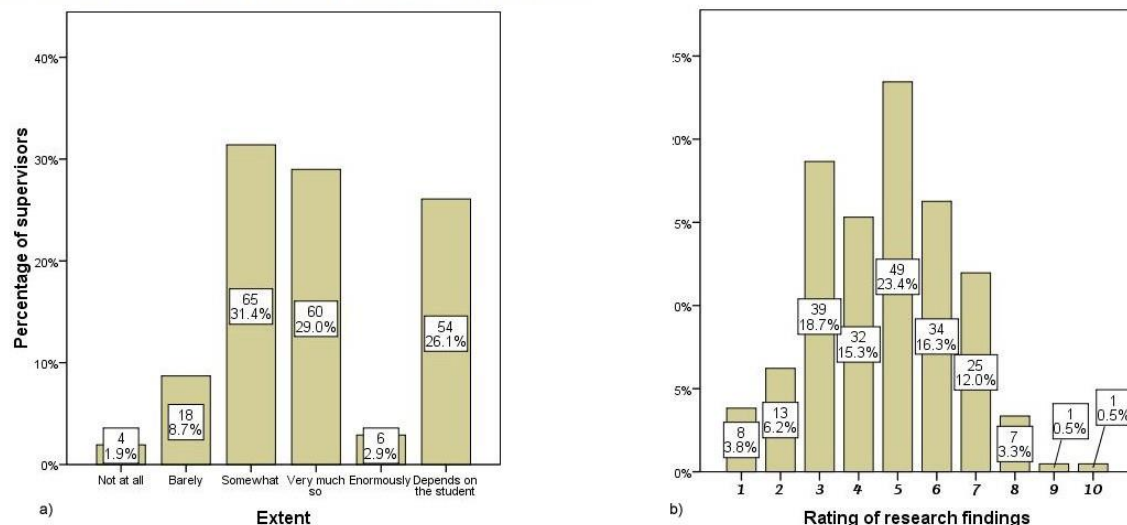
a. 'SSC4' denotes 'Year 4 Student Selected Component'.

b. See Q. 24

Equipping students for survival in a supercomplex world

26.5% (56/211) of supervisors reported having had the opportunity to supervise cross-disciplinary research (Q. 17). The breakdown of responses for supervisor encouragement of students to take risks and for supervisor ratings of student research findings is provided in Figure 1.

Figure 1. a) Extent to which supervisor would encourage an individual research student to take risks in exploring new areas and entering the unknown (Q. 25) and **b)** Supervisor ratings of student research findings on a spectrum from 1: norm endorsing to 10: revolutionary (Q. 20)



Of the 207 persons who provided a response to the question on the extent to which they would "encourage a given research student to take risks in exploring news areas of [the] subject area and thus enter the unknown" (Q. 25), 33 (15.9%) also offered free text comments. Some of these comments highlighted constraints on risk-taking behaviour

including the time constraints of the project and the lack of readiness of the student in terms of relevant background knowledge ($n = 12$), the requirement to conform to the evidence-based clinical practice guidelines recommended by SIGN ($n = 1$), competing interests in relation to a non-academic clinician's time to plan the project for the student and consider unknowns ($n = 1$) and supervisor sense of accountability to the grant provider if funding that they had been awarded was being used to support the student ($n = 1$). The issue with the SIGN guidelines was perceived as rendering the project "deficient from this point of view for the student", that is, in allowing scope for risk taking.

Concrete examples of risk-taking behaviour which supervisors encouraged included:

- the student taking their own photographs to add a more personal contribution to the design of eLearning materials
- development of new technology
- piloting of blue sky ideas
- use of approaches not commonly assumed within the research community of practise, including types of research methodologies (such as qualitative research) and exploration of "unfashionable areas" in clinical research

and

- allowing the student to embark on a literature search as an initial stage of their research in the history of medicine with neither the student nor the supervisor knowing if this search will yield any returns.

Out of a total of 210 supervisors who responded to the question on whether they perceived a difference in their experience of working with SSC4 students by comparison with working with other colleagues (see Q. 14), 95 (45.2)% confirmed that they did, while 50 (23.8%) claimed they were uncertain and 65 (31.0%) said that they did not. In terms of the types of differences encountered (Q. 15), 88 were potential obstacles to deep learning, while 73 were indicative of obstacles to preparing students for a supercomplex world. These two types of obstacle were each conveniently classified into 8 and 9 categories, respectively. By contrast, 90 suggestions had the potential to facilitate deep learning while 10 might facilitate preparation for a world of supercomplexity. These suggestions were readily classified into 8 and 4 categories, respectively. So as to provide an overall picture of the competing forces at large in providing student researchers with an optimal learning experience, the above categories are summarized in Table 4, together with the areas in which they overlap.

Table 4. Competing forces in SSC4' researchI aspiring to higher forms of learning.

Deep learning		Preparing for supercomplex world	
Inhibits	Promotes	Inhibits	Promotes
Considerable need for support in terms of guidance, direction, reassurance, encouragement, formation of research ideas and management to ensure completion	Personal ownership of project	Preconceptions of what is meant by "good" finding; sense that failed experiment amounts to failed project	Personal ownership of project
Students having different priorities from staff members	Having prior clinical experience	Lack of: clinical, lab or "lifetime" experience, clinical knowledge or knowledge of how NHS works	Steep learning curve
Little or no experience in research design, statistics, writing for research or literature searching; overall naivety regarding research; lack of organizational skills	Motivated to learn and enthusiastic	Expectation of limited autonomy, e.g. project already designed	Less bias about novel clinical perspectives and general openness to receiving or exploring new ideas
Lack of: clinical, lab or "lifetime" experience, clinical knowledge or knowledge of how NHS works	More sustained working relationship	Lack of obligation to engage with criticism or feedback	Greater scope in terms of permitted ideas for research
Expectation of limited autonomy, e.g. project already designed	Opportunity for better quality reports	Limitation in scope of projects, including opportunity for projects that require ethical approval, caused by time constraint	
	<i>Need for supervisor to structure project to allow them to impart knowledge to the student and facilitate successful completion</i>	Student needs more time than others to formulate ideas during project	
	More focused, better organized and areater incentive to complete, due to demands or structure of curriculum	Student wants clear results fast	
	Less bias about novel clinical perspectives and general openness to receiving or exploring new ideas	Student or supervisor senses that relationship is hierarchical rather than collegiate	
		Little or no experience in research design, statistics, writing for research or literature searching; overall naivety regarding research; lack of organizational skills	

a. "SSC4" denotes 'Year 4 Student Selected Component'.

b. **Less** specified otherwise, deficits or weaknesses refer specifically to the student.

c. **Italics** are used to highlight a characteristic which has the potential both to hinder and to promote a positive learning experience.

Impact of student researchI on curriculum redesign

The responses on whether student participation in Year 4 SSC4 research provides returns for curriculum design are provided according to year of study in Table 5.

Table 5. Supervisor views on whether experience of supervising SSC4^a research has caused them to redesign the content of one or more courses or programmes (including SSCs^a) so as to update material with current findings

		Course or programme redesigned			Total ^b
		Yes	No	Don't know	
Year of MBChB curriculum to which course or programme applies	1	6 6.9%	81 93.1%	0 0.0%	87
	2	5 6.6%	71 93.4%	0 0.0%	76
	3	3 3.1%	92 95.8%	1 1.0%	96
	4	3 2.4%	116 91.3%	8 6.3%	127
	5	4 4.6%	101 92.7%	3 2.8%	108

a. 'SSC' and 'SSC4' denote 'Student Selected Component' and 'Year 4 Student Selected Component', respectively.

b. Totals refer to those respondents who had indicated that they had contributed to teaching within the Edinburgh MBChB curriculum for the given year of the course. Using skip logic, the relevant follow-up part of the question was directed specifically to these supervisors (see Q.'s 4, 6, 8, 10 and 12).

Reported contributions to teaching in the above sense gleaned from the response data are provided in Table 6.

Table 6. Existing practises involving carry-over effects of SSC4 research to curriculum re-design in other areas of undergraduate medical teaching^{a,b}

Context	Innovation
SSC1 programme	i) Fresh emphasis on notion of evidence base, good literature searching techniques and time management; ii) supervisory practise changed based on better insight as to what could be realistically achieved during SSC1 projects, particularly with questionnaire studies; iii) "A couple of SSC4 groups were involved in developing the teaching of Global Health issues which is now a sub-unit in Semester 2 Health & Society."
Health and Society strand of Year 1 modules	i) response from organizer: content of information delivered to students regarding aspects of "our unusual patient population" informed by findings from SSC4s; ii) nature, experience and range of student learning "phenomenologically more holistic" (such as through making students more aware of existing clinical practise and relevant health inequalities)
SSC2	i) "Worked on a research model of investigation, analysis and reporting for my most recent SSC2 group"; ii) greater emphasis on literature searching and developing a questioning attitude; iii) hosting different groups of SSC2 students over three consecutive years constructing Wikis for their projects on health and homelessness
Lecturing in Year 2	Used data on the bacterial infection <i>Clostridium difficile</i> (C diff) from SSC4 work in 3 lectures
Teaching of Refugee Health as part of Year 3 <i>Vertical Themes Week</i> , where students are exposed to key issues within the different Vertical Themes of the MBChB programme through a comprehensive series of lectures and workshops	Previous SSC4 students who had researched the experience of Asylum Seekers in Lothian presenting their research to current Year 3 students
In-theatre teaching and teaching in ICU (Year 4)	Students are encouraged to consider recent or good research findings in patient management
Year 5 Surgery - Anaesthesia and critical care	Sharing what other students have done, such as in the case of SSC4 projects on theatre monitors, so as to expand existing knowledge
ICU teaching in Year 5	Students are encouraged to refer to 4 research findings when handling case presentations in ICU.

a. 'SSC1', 'SSC2' and 'SSC4' denote 'Year 1', 'Year 2' and 'Year 4 Student Selected Component', respectively.

b. Ideas gleaned from SSC4 supervisors who contribute to non-SSC4 teaching (see Q. 15)

Discussion

The respondents' profiles reflected, not only a wide range of areas of expertise but also, considerable experience in having supervised students to the point of completion. This was helpful in terms of gaining a holistic perspective on the SSC4 experience largely informed by personal and hence potentially more accurate experiences of supervisory practises.

While it was encouraging to note that the recognition of an opportunity to get involved in teaching was the second most popular reason for taking on the role of supervisor, the corresponding proportion of 32% was rather low. This points to the possible need to encourage more creativity and planning within the supervisor-student relationship in

terms of ensuring that the student experience is more educationally formative and not solely perceived in terms of research output. Furthermore, if the findings of this study reflect a more widespread opinion among clinicians regarding the supervision of undergraduate research, then such motivation may need to be provided very explicitly by course organizers, given the relatively low proportion (25.3%) of supervisors who claimed to be at least partly driven by the sense of value added to their own PPD.

The lack of statistical evidence for an association in terms of supervisors opting for the two most popular reasons is supportive of a research-teaching nexus in so far as it is not evident that foreseeing research opportunities and anticipating teaching opportunities are competing forces. Nevertheless, for there to be an optimal synergy between research and teaching, there ought to be evidence for a *positive* correlation between these two conceptions of the supervisory role.

The finding that it is most often and so often the case (66.4% of responses) that supervisors are motivated by having research opportunities for prospective students at their fingertips is, however, reassuring in terms of the sustainability of the SSC4 programme as a vehicle for including undergraduate medical students in communities of research practise.

Facilitating Higher Forms of Learning

In evaluating the results in Table 1, one should bear in mind that Baxter Magolda's model originates from a context involving the experiences of adult learners progressing through a journey of self-discovery, commencing at entry to college in 1986 and continuing beyond graduation. (Baxter Magolda, 1992)

Given this initial qualification, it is uplifting to observe that the majority of responses in Table 1 fall to the right of the main diagonal elements, reflecting the perception in most cases that undergraduate students are undergoing a positive transition in their level of learning style as a result of their participation in clinically related research projects. The most popular view (approximately one quarter of cases) was that students progress from the most elementary stage of obtaining knowledge from the instructor to that of thinking for themselves, etc., the exceptional cases being those where the supervisor indicated that they were unsure of the appropriate response to choose. This particular type of progress is perhaps indicative of a realistic goal to aspire to within a context, such as the Edinburgh SSC4, where students have limited, if any, prior research experience and the existing period of research is relatively short. It would appear from the literature, however, that the application of Baxter Magolda's model to this particular context is unique and thus with future studies in mind, it is a valuable exercise to acknowledge in what senses it is implicit from supervisor responses that this model of progression in learning could be profitably honed for such a context. The ideas derived from the responses of highlighting progress in analytical thinking within the descriptors and of applying the model in a task-specific manner rather than holistically to research are important in this respect.

In terms of the practicalities of enhancing student learning experiences as researchers, the value of becoming a member of a community of research practise has already been recognized. Here, the supervisor is responsible for fostering an environment for the learner to engage in knowledge construction, either in the form of radical findings or through negotiation of perspectives on existing knowledge. (MacDougall & Riley, 2010) A fundamental requirement for the creation of such an environment for the research student is their involvement in existing research which is important to the life of a department or team.

It is noteworthy, therefore, that the findings in Table 2 suggest that the quality of student learning would benefit from better integration of student research activities with

the existing research activities of the supervisor's team or of a suitably chosen allied research team (if the supervisor is not research active). This requires careful planning on the part of the supervisor, both in terms of connecting students with others at an early stage and creating opportunities such as pilot projects with achievable endpoints which have the potential to inform future research. More generally, from Tables 2 and 3, it appears that the responsibility of project design tends to be more heavily weighted towards supervisors than students. In terms of development of mutual trust between the student and the supervisor and what Barnett calls exposure to "risk of self-organization" (Barnett, 2007), opportunities for student autonomy are therefore limited. This serves to reinforce the observation made in a related study of a "lack of prior research experience and the resultant need for extensive training in research design". (MacDougall & Riley, 2010)

Equipping Students for Survival in a Supercomplex World

Over a quarter of supervisors reported having had the opportunity to supervise cross-disciplinary research projects. Given the constraints of time and prior learning, this is rather an encouraging result. However, in terms of Barnett's ideals for handling multiplying and competing perspectives, there is clearly room for improvement. This suggests that programme organizers ought to be pro-active in the promotion of interdisciplinarity through incorporating this practise into their recommendations for supervisory practise.

By contrast, from Figure 1 a), it appears that a considerably greater proportion of supervisors are preparing their students well for managing uncertainty, with over 63% of respondents claiming that they would more than just barely encourage a given student to take risks in exploring new areas. In turn, the concrete examples listed above of risk-taking behaviour are sufficiently diverse to serve as useful primers to supervisors as avenues to pursue in creating opportunities for exposing students to risk. It might be added though, particularly in relation to the last of these examples, that there is also the need to ensure that failure on account of risk-taking does not impinge upon a project in its entirety. Ideally, students should be rewarded for their efforts, with dead ends being recognized as discoveries to inform future research endeavours and well-designed escape routes in place well in advance of the project start date. It is also important to stress that all of these examples are realistic in terms of creating opportunities for students to encounter risk without compromising patient safety.

About a quarter of supervisors reported that level of encouragement to engage in risk-taking would depend on the student (Figure 1a). By way of investigating this idea further, it is intended in a later paper based on student data to investigate what types of student are exposed to this and other opportunities for preparing for the conditions of supercomplexity.

Supervisor comments about constraints on opportunities for promoting risk taking activities in student research may point to the need for project development in the form of pilot studies, as illustrated in the supervisor recommendation of piloting blue sky activities. In response to one supervisor's comment, regarding accountability to a grant provider, it is not typically the case at Edinburgh that a grant previously awarded to a supervisor for clinical research is intended for use by a fledgling researcher within the constraints of a 14-week project. Thus, a minority of supervisors may need to reconsider the appropriateness of such a strategy, not to mention its utility in the student's transition to more advanced approaches to learning or preparation for coping with uncertainty and risk.

The limitations posed on projects dependent on use of SIGN guidelines also surfaced on a number of occasions. This points to the need to find more innovative means of designing research projects involving non-negotiable treatment protocols so to ensure

that participating students are not disadvantaged in the transition to more mature approaches to learning or in the availability of opportunities for exposure to more risk-orientated challenges.

A majority (69%) of supervisors were unprepared to regard working with students as the same as with other colleagues. The reasons for a difference summarized in Table 4 place an emphasis on student naivety in terms of research experience, lack of student skills for research and the need for supervisors to accommodate the associated student needs and expectations, particularly given the limited time the student has to complete their project. This was to some extent counter-balanced by the differences which *promoted* optimal learning, but much more so in the case of deep learning than preparation for a supercomplex world.

Greater degrees of motivation to complete the work, openness to new ideas and freedom to pursue these ideas were encouraging examples of differences with the potential to enhance deep learning and preparation for managing super-complexity. The need for supervisor intervention might ensure more purposeful learning as well as presenting a barrier to autonomy. This has been recognized in Table 4 in terms of the potential to *both* promote and inhibit deep learning. The study findings suggest more generally, however, that for deep learning to be more fully realized, a key concern to address is the deficit in prior learning of relevance to student roles as researchers. Correspondingly, there is considerable scope for investigating opportunities for mainstreaming research within the undergraduate medical curriculum. In defence of the face validity of such a model in relation to undergraduate medicine, it is noteworthy that recent research confirms that there is a consensus that constraints imposed by external governing bodies do “not hinder ... the input of a research ethos into the undergraduate curriculum.” (Struthers, Laidlaw, & Aiton, 2008)

In terms of the closely connected areas of facilitating students’ progression from norm endorsing to revolutionary forms of research, the symmetrical distribution in Figure 1b) suggests that supervisor perceptions are weighted toward the middle of the spectrum. Given the limited exposure of undergraduate medical students at Edinburgh to research, this is an extremely positive finding in relation to preparing students to become clinical researchers capable of providing Barnett’s alternative “frames of understanding” to patients in a supercomplex world.

Impact of Student Research on Curriculum Design

The proportions of supervisors who perceived themselves as having re-designed curriculum content in any one year as a result of SSC4 student research are exceptionally low (Table 5), ranging from 2.4% in Year 4 to 6.9% in Year 1. This finding may reflect the fact that the idea of involving students in curriculum re-design is a relatively new one as well as possible disparity between SSC4 research and the types of non-SSC4 courses, if any, that supervisors are delivering. In terms of the reciprocity of research and teaching, this points to the need for supervisors to seek opportunities within the undergraduate medical curriculum as a whole for students to share their research findings and sense that they, as teachers, are contributing to student learning through the medium of research. This ought to involve finding and connecting the students with the relevant course contacts to facilitate good planning in course delivery.

The examples provided in Table 6 rarely directly involve the student researcher and tend to lack evidence that it is the educator’s *intention* to ensure a carry-over effect of student research to curriculum re-design. This suggests the existence of a subtle divide between research and teaching based on stereotyping of the role of the researcher which may need to be addressed. One way forward in this respect would be to seek research supervisors’ contributions to future research involving the identification of innovative ways of carrying forward the research work of their students into other teaching contexts

within the undergraduate medical curriculum. By way of convincing medical educators more generally of the potential for enhancing research-teaching linkages within their individual specialties, key areas of enquiry here would be the rationale behind each innovation and how exactly it should be implemented.

Limitations

The survey response frequency (217) and rate (67%) for this study were very encouraging, as was the frequency of specialist areas of research supervision (126). Nevertheless, it is important to acknowledge the fact that several supervisors highlighted the difficulty of generalization of results across their students in the application of Baxter Magolda's epistemological reflection model for evaluating transition to more advanced stages of learning. A closer examination of such transitions could be achieved by means of a longitudinal study whereby supervisors are enabled to monitor individual student progress over a fixed time period. As the 14-week period of the SSC4 module is relatively short, returns from such work could be further enhanced within a context where student research is mainstreamed throughout the curriculum from induction to final year.

The practise of mainstreaming and integrating research within university curricula has been recommended by Healey and Jenkins via the notion of a "research active curriculum" (Healey & Jenkins, 2009). Correspondingly, very positive progress has been made in terms of successful exemplars of "the integration of research and inquiry into the induction process for new undergraduate students" in a range of departments at the University of Gloucestershire, with the result that this practise has become a "signature pedagogy for parts of the University". Additionally, an initiative at the University of Northumbria (UoG, 2011) to enhance research-teaching linkages by redesigning the curriculum to involve students in research in Childhood Studies throughout Year 1 has led to encouraging results within the School of Health, Community and Education Studies.

In terms of extending this type of work to include *all* years of an undergraduate curriculum, useful starting points for building on might include existing practise within the School of Geography and Earth Sciences at McMaster University, Canada and the Department of Chemistry at Utrecht University, the Netherlands, where the curricula have been developed "from year 1 to postgraduate levels to progressively develop students as researchers." (Jenkins, Healy, & Zetter, 2007) The well-established practise of mainstreaming problem-based learning within the undergraduate medical curriculum at McMaster University (Healey & Jenkins, 2009) is also of relevance here.

The lack of evidence that undergraduate research is re-shaping the nature of curriculum content in other areas of the curriculum should not be misread as the lack of potential for establishing this particular type of research-teaching linkage. Indeed, in a recent literature review, it has been observed more generally throughout undergraduate teaching that there is considerable debate concerning whether undergraduates should participate in curriculum design. (Bovill, Morss, & Bulley, 2009) Thus, while such participation could be supported through involving research students in in-class presentations to different year groups and through inclusion of completed research as case studies in more conventional teaching approaches, there is still much need for research within such contexts to assess the added value to students, both as consumers and providers of teaching innovations.

Conclusions

While the findings of this study strongly support the existence of a research-teaching nexus in terms of supervised student research being an effective pedagogical tool for beneficial learning, there is potential for improvement in terms of strengthening the links which hold this nexus in place.

A persistent theme from the findings of the current study is the impediment which lack of prior experience in research is having on progression to higher forms of learning and in equipping medical students for a supercomplex world. This is particularly clear in relation to allowing students to exercise autonomy in project design and to collaborate in more revolutionary forms of research. The above issues are compounded by the time constraint posed by the 14-week Edinburgh SSC4. However, they are likely to re-surface on an international scale, given the considerable variety of additional contexts which have already been recognized (MacDougall & Riley, 2010) where undergraduate medical students currently embark on short-term research projects.

With reference to the SSC4 programme in particular, more needs to be done in terms of planning the project for the student to ensure integration with existing or future research of significance to the research team, creating opportunities for students to engage in interdisciplinary research and in finding opportunities for SSC4 students to communicate their findings to students within other areas of the curriculum. The latter need may point to a more general requirement for supervisors to be more adequately versed in the core content of medical curricula in order that they are better placed to create opportunities for student presentations aimed at enhancing the learning experiences of students in other areas of the medical curriculum.

The application of Baxter Magolda's epistemological reflection model within the context of the Edinburgh SSC4 programme has proved informative as a means of identifying evidence that engagement of undergraduate medical students in research is associated with progression to higher forms of learning. Additionally, constructive feedback from supervisors suggests the need for further development of this model to fit the above type of learning context. It also provides the basis for future research of a longitudinal nature which allows the revised model to track the learning progress of *individual* students.

Encouragingly so, considerable proportions of SSC4 supervisors at Edinburgh have expressed openness to taking students beyond their comfort zone through allowing them to engage in more revolutionary forms of research and to take risks in exploring new areas. In the latter case, the exemplars of related practises obtained from respondents may prove valuable to organizers of undergraduate research programmes in motivating supervisors to prepare students for managing uncertainty.

However, the findings of this study should also provide the impetus for organizers of short-term research programmes to explore in a more general sense how best to present course materials for promoting research-teaching linkages. This is entirely consistent with observations made elsewhere that such linkages "do not necessarily occur naturally" and that even in a research-intensive university, supervisors may have a tendency to be reticent about reading the "program description or guidelines". (Jenkins et al., 2007; Wilson, Howitt, Wilson, & Roberts, 2011) In particular, while the establishment of research-teaching linkages was identified by the Scottish Quality Assurance Agency during 2006 - 2008 as one of their Quality Enhancement Themes for improving graduate attributes, the need remains for communicating the rationale behind this venture to subject specialists, including clinical practitioners within professionally orientated disciplines. There is also an onus on course organizers of short-term research projects to include related information in study guides, induction packs and other supervisory training materials, with a particular emphasis on the role of the supervisor as educator. (MacDougall & Riley, 2010)

Additional files

Additional file

Title: SSC4 Survey for Past and Present Supervisors

Description: pdf version of entire online questionnaire used for Higher Education

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